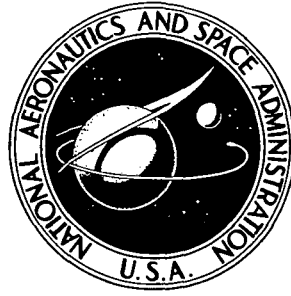


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**THE EFFECT OF CANARD AND VERTICAL TAILS
ON THE AERODYNAMIC CHARACTERISTICS
OF A MODEL WITH A 59° SWEEPBACK WING
AT A MACH NUMBER OF 0.30**

by William P. Henderson

Langley Research Center

Hampton, Va. 23665



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SUMMARY

An investigation has been conducted to determine the effects of canard, canard location, vertical tails, and vertical-tail location on the aerodynamic characteristics of a model having a 59° sweptback wing. The investigation was conducted at a Mach number of 0.30, at angles of attack up to 22° and at sideslip angles of 0° and $\pm 5^\circ$.

The results of the study indicate that adding the canard to the model had only a slight effect on the lift at the lower angles of attack. At the higher angles of attack there is a significant effect of canard height on lift, the canard in the high location (above the wing chord plane) resulting in the highest lifts. The lift and drag characteristics are predicted well for the configuration with the mid or high canard locations by combining a potential flow solution on the canard with a potential plus vortex solution on the wing. Variations in the canard height significantly affect the pitching-moment characteristics of the configuration; the configuration with the low or mid canard location exhibits an increase in stability at the higher lift coefficients, whereas the configuration with the high canard exhibits pitch-up. Adding the vertical tails in the outboard location caused a significant loss in lift at the higher angles of attack; this lift loss was eliminated by moving the vertical tails inboard. All the vertical-tail locations studied resulted in a stable increment in directional stability throughout the test angle-of-attack range. The increment in vertical-tail effectiveness was considerably smaller for the mid wing configuration with the inboard vertical tails than for the other configurations studied.

INTRODUCTION

The National Aeronautics and Space Administration is currently conducting generalized studies on the use of canards as a means of increasing the maneuvering potential of advanced aircraft. The use of canards offers several attractive features, such as increased trimmed lift capability and the potential for reduced trimmed drag. (See ref. 1.) In addition, the geometric characteristics of close-coupled canard configurations offer a potential for improved longitudinal progression of cross-sectional area; this improvement

could result in reduced wave drag at low supersonic speeds. References 2 and 3 present systematic studies of the effect of canard location on the canard-wing lift interference for a configuration having a 44° sweptback wing. The studies presented in these references included an additional wing having a leading-edge sweep angle of 59° , but the data regarding this wing are very limited. The purpose of this paper is to extend the earlier investigations by studying, in more detail, the effects of canard location on this configuration. The studies of references 2 and 3 were also limited to the longitudinal characteristics. Therefore, the present investigation includes a study of the effects of vertical-tail location on the lateral-directional characteristics as well as the effects on the longitudinal characteristics. The investigation was conducted in the Langley 7- by 10-foot tunnel at a Mach number of 0.30, at angles of attack up to 22° and at sideslip angles of 0° and $\pm 5^\circ$.

SYMBOLS

The results are referred to the body-axis system with the exception of the lift and drag coefficients, which are referred to the wind-axis system. The moment reference center was located at a point 56.97 cm rearward of the nose along the model reference line. (See fig. 1.)

b	wing span, 50.80 centimeters
C_D	drag coefficient, $\frac{\text{Drag}}{qS}$
C_L	lift coefficient, $\frac{\text{Lift}}{qS}$
C_l	rolling-moment coefficient, $\frac{\text{Rolling moment}}{qSb}$
$C_{l\beta}$	effective-dihedral parameter, $\frac{\Delta C_l}{\Delta \beta}$, per degree
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qS\bar{c}}$
C_n	yawing-moment coefficient, $\frac{\text{Yawing moment}}{qSb}$
$C_{n\beta}$	directional-stability parameter, $\frac{\Delta C_n}{\Delta \beta}$, per degree
C_Y	side-force coefficient, $\frac{\text{Side force}}{qS}$
$C_{Y\beta}$	side-force parameter, $\frac{\Delta C_Y}{\Delta \beta}$, per degree
\bar{c}	wing mean geometric chord, 23.30 centimeters

q	free-stream dynamic pressure, newtons per meter ²
S	wing reference area, 0.10322 meter ²
y_v	spanwise location of vertical tail with respect to plane of symmetry, centimeters
z_c	vertical location of canard with respect to wing chord plane, centimeters
α	angle of attack, degrees
β	angle of sideslip, degrees
Δ	increment in forces or moments

MODEL DESCRIPTION

A three-view drawing of the model is shown in figure 1(a). Figure 1(b) presents a sketch of the model showing the various canard and wing locations studied. A photograph of the model sting mounted in the Langley high-speed 7- by 10-foot tunnel is presented in figure 2. The wing as illustrated in figure 1(a) has an aspect ratio of 2.5, a taper ratio of 0.20, a wing-leading-edge sweep of 59° , and an uncambered NACA 64A series airfoil section (measured streamwise) with a thickness ratio of 6 percent at the fuselage juncture and 4 percent at the wing tip. The canard was untwisted and had a leading-edge sweep angle of 51.5° and an uncambered circular-arc airfoil section. The thickness ratio varied linearly from 6 percent at the root to 4 percent at the tip. As shown in figure 1(b), the canard was tested in the chord plane of the wing and in locations above and below the wing. The vertical tails had a leading-edge sweep angle of 47° and an uncambered 64A series airfoil section with a thickness ratio of 4 percent, and they were tested in the locations shown in figure 1(a).

TEST AND CORRECTIONS

This investigation was conducted in the Langley high-speed 7- by 10-foot tunnel. Since the tunnel operation was limited because of fan blade problems, the tests were made only at a Mach number of 0.30 which corresponds to a Reynolds number based on \bar{c} of 1.5×10^6 . The angle-of-attack range varied from -4° to 22° at sideslip angles of 0° and $\pm 5^\circ$. Transition strips 0.32 cm wide of No. 100 carborundum grains (based on analysis of ref. 3) were placed 1.14 cm streamwise from the leading edge of the wings and 2.54 cm behind the nose of the fuselage.

Because of aerodynamic load, corrections to the model angle of attack have been made for deflections of the balance and sting support system. Pressure measurements obtained from orifices located within the fuselage base cavity were used to adjust the drag coefficient to a condition of free-stream static pressure at the model base. Jet boundary and blockage corrections were estimated and found to be negligible and therefore were not applied to the data.

PRESENTATION OF DATA

An outline of the contents of the data figures is as follows:

	Figure
Effect of canard location on the longitudinal aerodynamic characteristics of the model with the mid wing location. Vertical tails off	3
Comparison of experimental and estimated lift and drag characteristics for the model without the canard or vertical tails	4
Comparison of experimental and estimated lift and drag characteristics for the model with the mid wing and high canard locations. Vertical tails off . . .	5
Comparison of experimental and estimated lift and drag characteristics for the model with the mid wing and mid canard locations. Vertical tails off	6
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Effect of canard location on the longitudinal aerodynamic characteristics of the model with mid wing location. Vertical tails located at $0.727b/2$	8
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RESULTS AND DISCUSSION

Effect of Canard Height on the Longitudinal Characteristics

The effect of varying the vertical location of the canard with respect to the wing on the aerodynamic characteristics of the model with the mid wing location is presented in figure 3. Adding the canard had no significant effect on the lift at the lower angles of attack; thus, the direct lift associated with adding the canard area is balanced by a loss in lift on the wing due to the canard downwash flow field. At the higher angles of attack, above 8° , the canard height has a significant effect on the lift coefficient developed by the configuration. At the highest test angle of attack the canard in the low position produces only a slight increase in lift above the canard-off curve. Raising the canard to a position above the wing chord plane results in a significant increase in lift coefficient, an increment of about 0.25 at an angle of attack of 21° .

The flow mechanism which produces these results can be explained using the summary data of figures 4 through 7. Figure 4 presents a comparison of calculated lift and drag with experimental data for the wing-body configuration (canard off). The solid line represents the calculated lift, based on the potential flow theory of reference 4, and the dashed curve represents the potential plus vortex lift theory of reference 5. The experimental lift data (circular symbols) agree with the potential plus vortex lift theory up to an angle of attack of about 10° ; this agreement indicates the formation of a leading-edge vortex and the accompanying vortex lift. Above an angle of attack of 10° , the vortex probably breaks down and full vortex lift is not obtained. The drag data at high lift coefficients would then naturally agree with the theoretical estimate for zero leading-edge suction and no vortex lift.

When the canard is placed in the mid or high position (see fig. 5 or 6) the canard flow field interacts with the wing vortex, and delays vortex breakdown to an angle of attack beyond the range of the wind-tunnel tests. The wing flow field, in turn, interacts with the canard flow field and aids in keeping the canard flow field attached over the angle-of-attack

range of the test. The difference in lift between the model with the high and mid canard locations appears to be due primarily to the difference in downwash generated on the wing by the different canard locations.

For the model with the low canard location, the experimental data (see fig. 7) agree with the total potential flow estimate and indicate the possible absence of vortex lift on the wing. However, it is not clear from these data whether the reduced lift is the result of a loss of vortex lift on the wing or a loss of lift on the canard.

The lift characteristics on the canard and wing combine in such a manner as to result in the pitching-moment characteristics illustrated in figure 8. The configuration with the canard in the low or mid position exhibits a significant increase in stability at the higher lift coefficients, whereas the configuration with the high canard position exhibits a pitch-up. As indicated in the section on model description, the wing is untwisted and does not incorporate maneuvering devices. With careful consideration to the wing design, these nonlinearities can possibly be eliminated.

Effect of Vertical Tails on the Longitudinal Characteristics

Adding the vertical tails to the configuration at $\frac{y}{b/2} = 0.727$ caused a significant loss in lift at the higher angles of attack. (See fig. 9.) The vertical tails in this location (see fig. 1) probably act as a wing fence and shield the outboard part of the wing from the beneficial effects of the vortex flow field.

Moving the vertical tails inboard (fig. 10) eliminated the loss in lift up to angles of attack of 20° . This effect is not surprising since the vertical tail would be moving away from the leading-edge vortex flow field.

Effect of Vertical Tails on the Lateral-Directional Characteristics

The lateral-directional stability characteristics for the configuration with the mid wing and high canard locations are presented in figure 11. The wing-body-canard directional-stability level is very unstable; this condition is expected when the shape of the fuselage is taken into consideration. Both of the vertical-tail locations studied exhibited a stabilizing increment in directional stability throughout the test angle-of-attack range. There appears to be a considerable difference in the level of directional stability exhibited by the configuration with the two different vertical-tail locations. This difference must be associated with the location of the vertical tails with respect to the wing-canard flow fields.

The aerodynamic characteristics for the configuration with the high wing location are presented in figures 12 to 16. These data show trends which are similar to those exhibited by the mid wing configuration, except for the directional stability characteristics. The

large reduction in the directional stability parameter $C_{n\beta}$, which was evident for the inboard vertical-tail location on the mid wing configuration, did not appear for the high wing location.

The reader should be cautioned that, although the present investigation was made with the canards undeflected, there may be some areas where canard deflection may significantly affect the results.

SUMMARY OF RESULTS

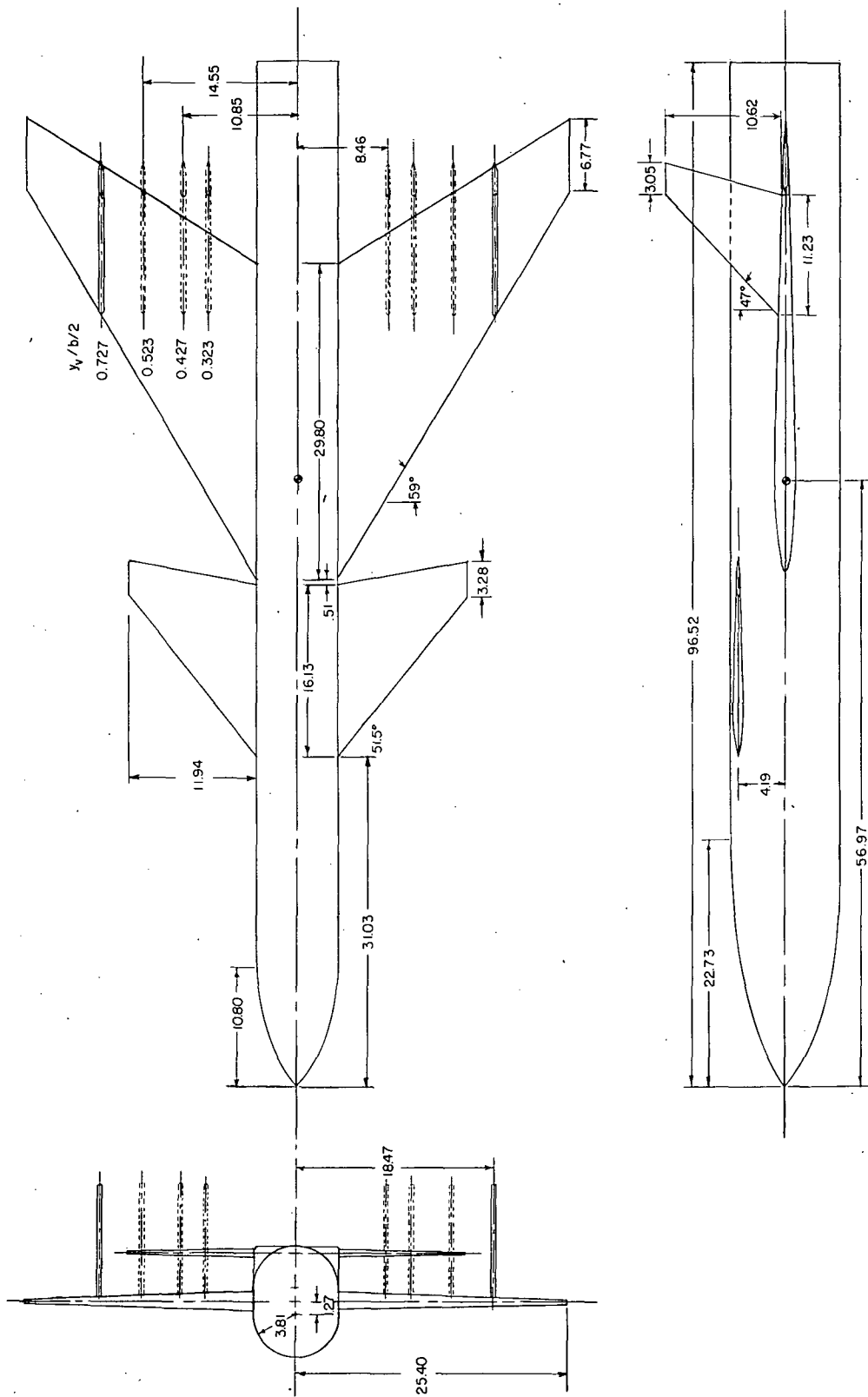
The results of the investigation to determine the effect of canard and vertical-tail location on the aerodynamic characteristics of a model having a 59° sweptback wing are summarized as follows:

1. Adding the canard to the model had only a slight effect on the lift at the lower angles of attack. At the higher angles of attack the canard height has a significant effect on lift; the canard in the high location (above the wing chord plane) results in the highest lift coefficients.
2. The lift and drag characteristics are predicted for the configuration with the mid or high canard locations by combining a potential flow solution on the canard with a potential plus vortex solution on the wing.
3. Variations in canard height significantly affect the pitching-moment characteristics of the configuration, in that the configuration with the low or mid canard location exhibits an increase in stability at the higher lift coefficients, whereas the configuration with the high canard exhibits pitch-up.
4. Adding the vertical tails in the outboard location caused a significant loss in lift at the higher angles of attack. This lift loss was eliminated by moving the vertical tails inboard.
5. All the vertical-tail locations studied resulted in a stable increment in directional stability throughout the test angle-of-attack range. The increment in vertical-tail effectiveness was considerably smaller for the mid wing configuration with the inboard vertical tails than for the other configurations studied.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., June 18, 1974.

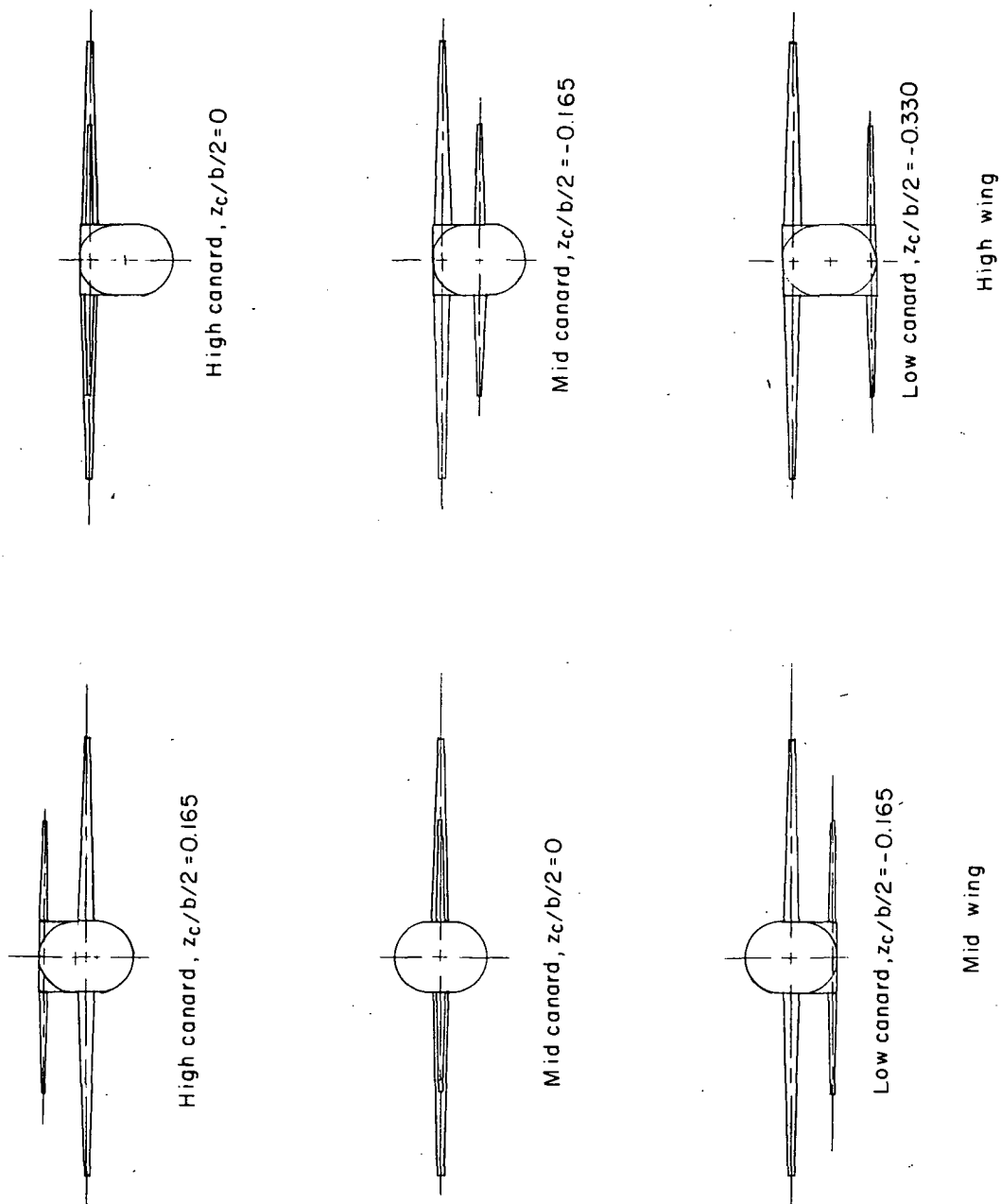
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(a) Mid wing, high canard.

Figure 1.- Drawing of the models studied. (Dimensions are in centimeters unless otherwise noted.)



(b) Canard-wing combination studied.

Figure 1.- Concluded.

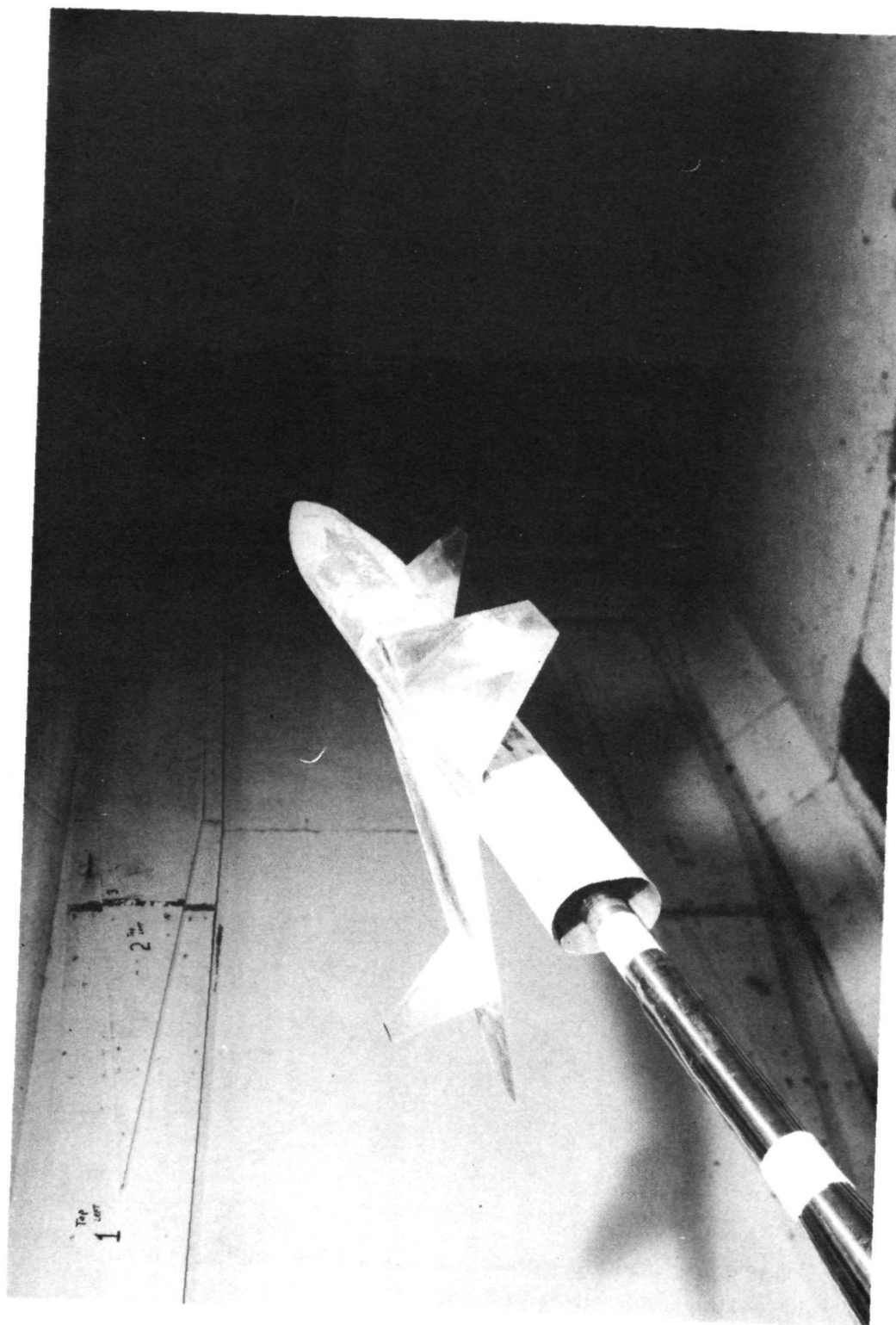


Figure 2.- Photograph of model in the Langley high-speed 7 - by 10-foot tunnel.

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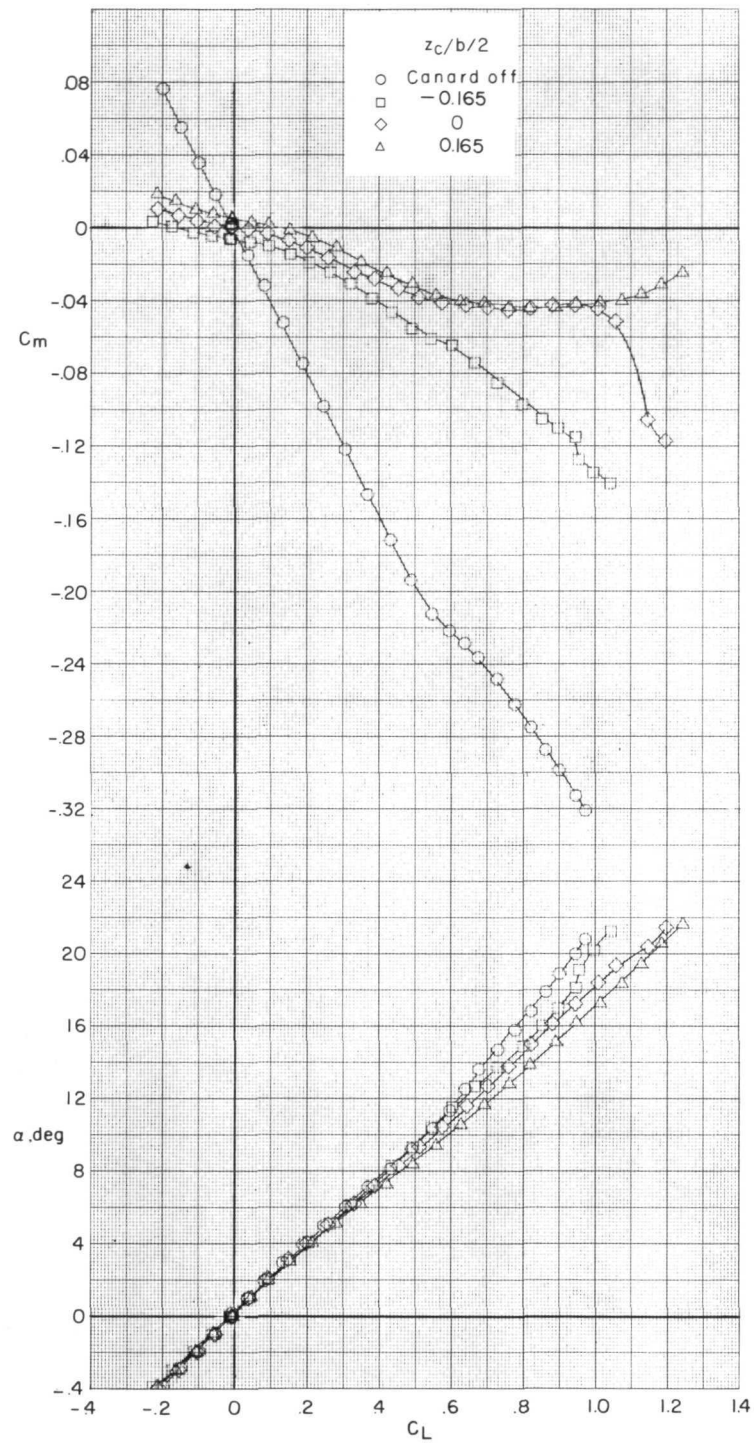


Figure 3.- Effect of canard location on the longitudinal aerodynamic characteristics of the model with mid wing location. Vertical tails off.

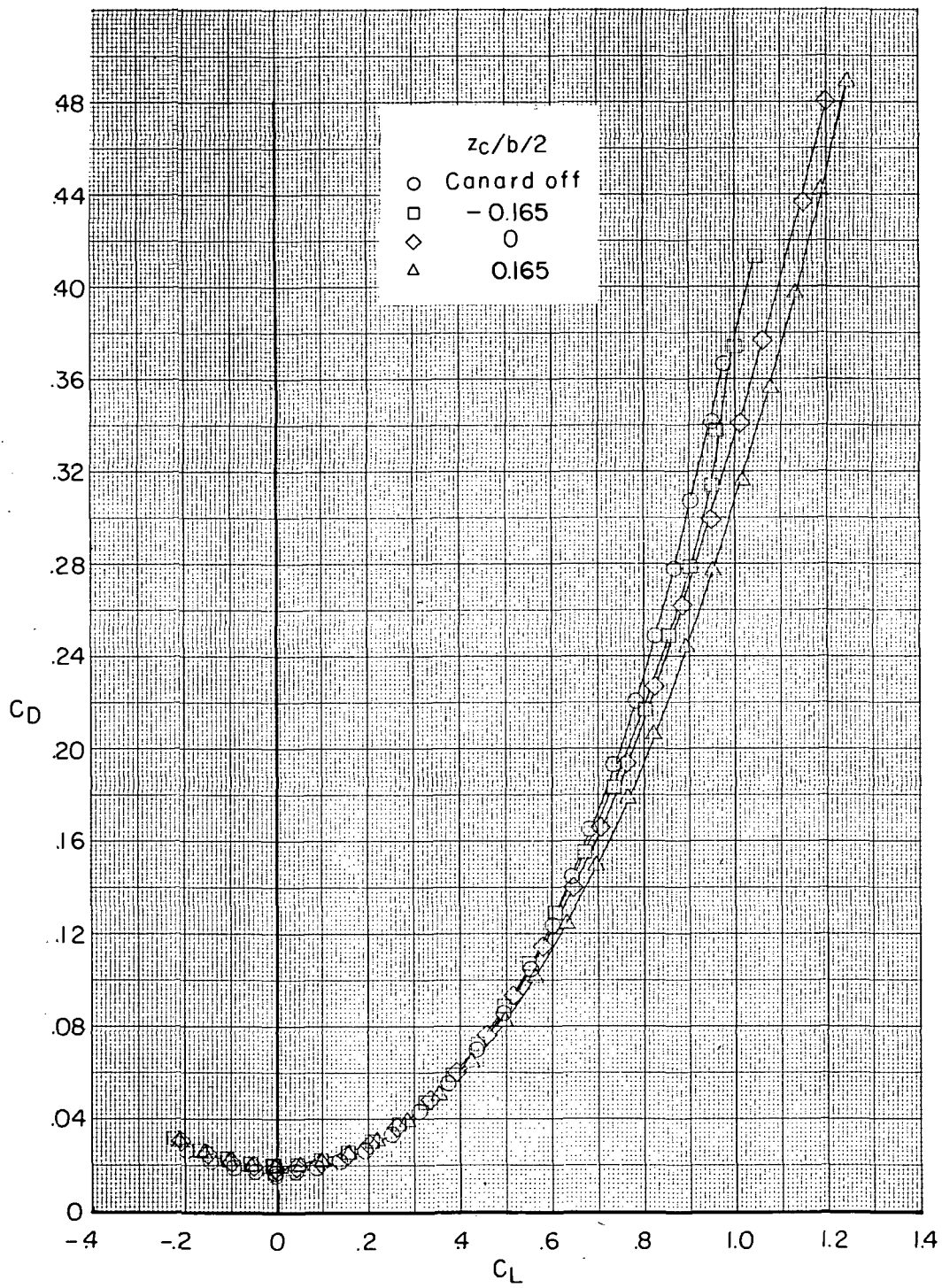


Figure 3.- Concluded.

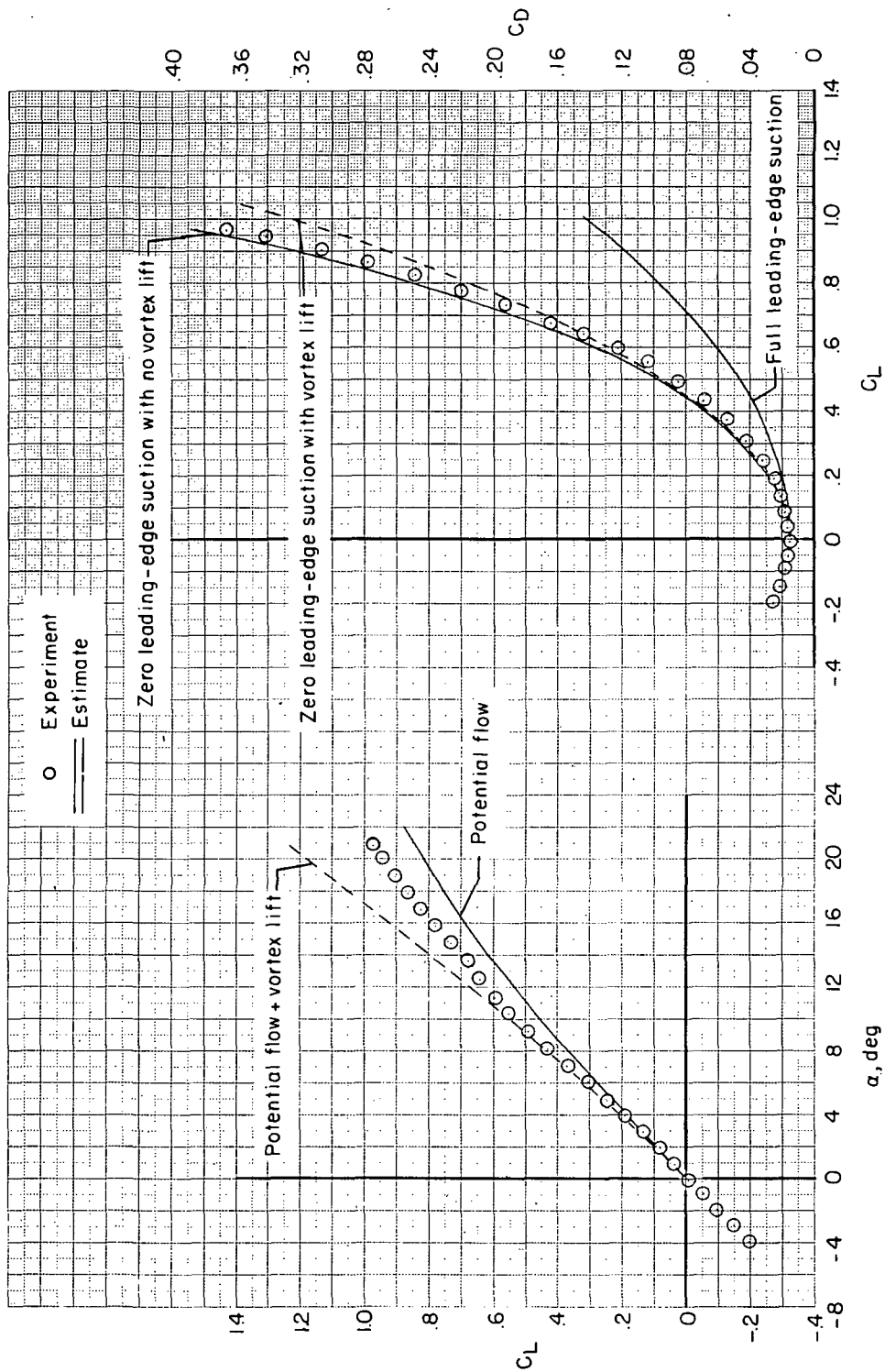


Figure 4.- Comparison of experimental and estimated lift and drag characteristics for the model without the canard or vertical tails.

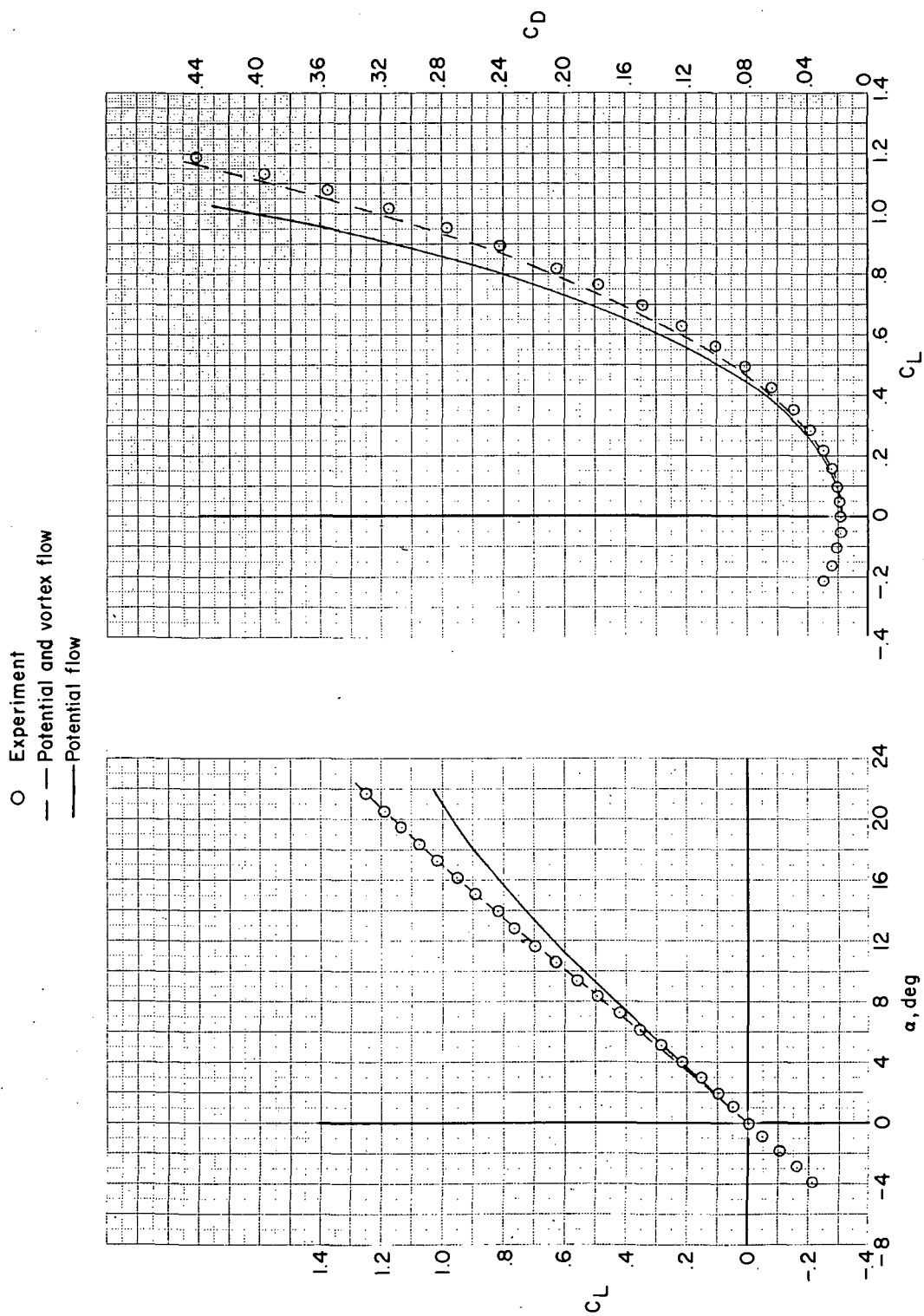


Figure 5.- Comparison of experimental and estimated lift and drag characteristics for the model with the mid wing and high canard locations. Vertical tails off.

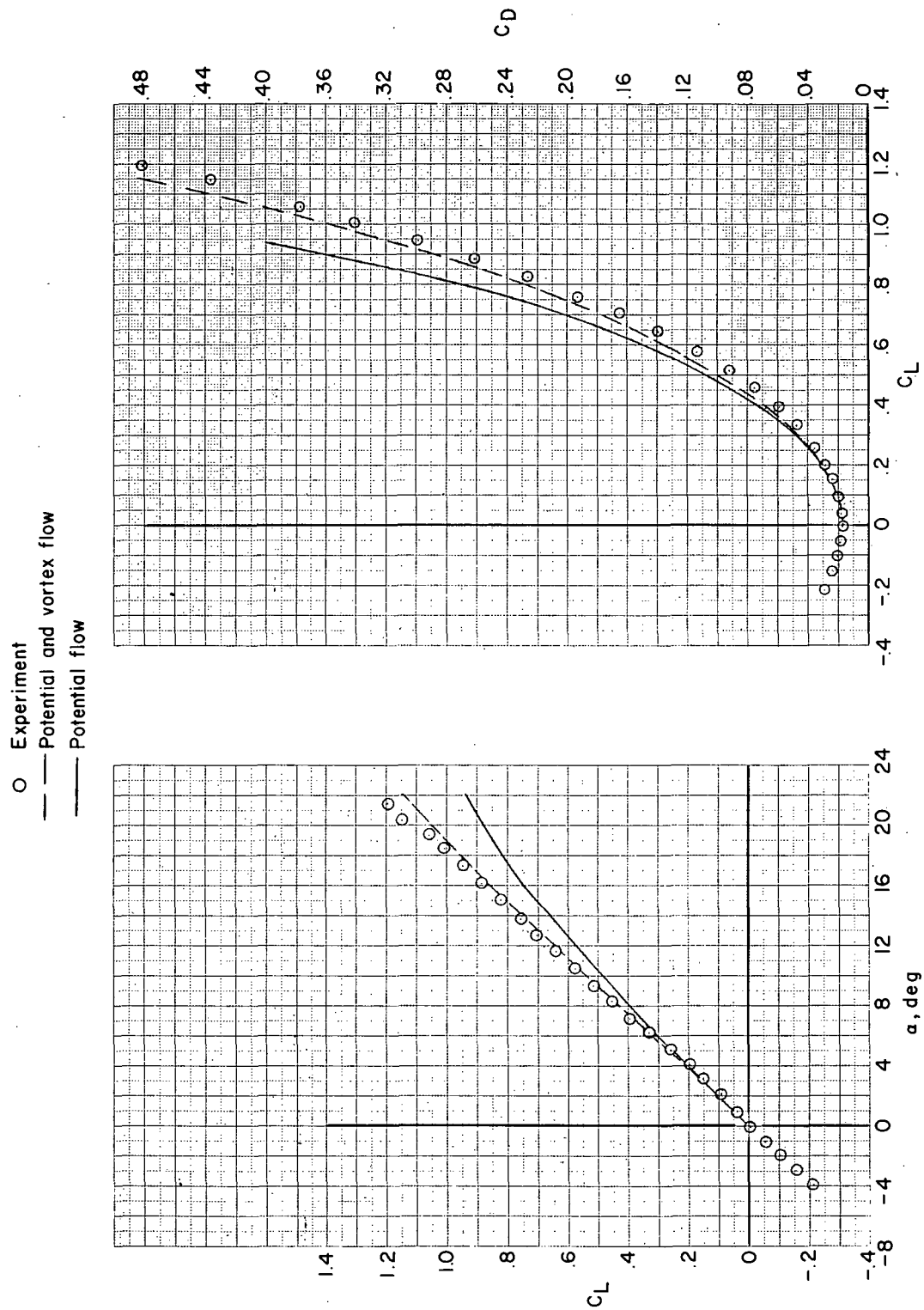


Figure 6.- Comparison of experimental and estimated lift and drag characteristics for the model with the mid wing and mid canard locations. Vertical tails off.

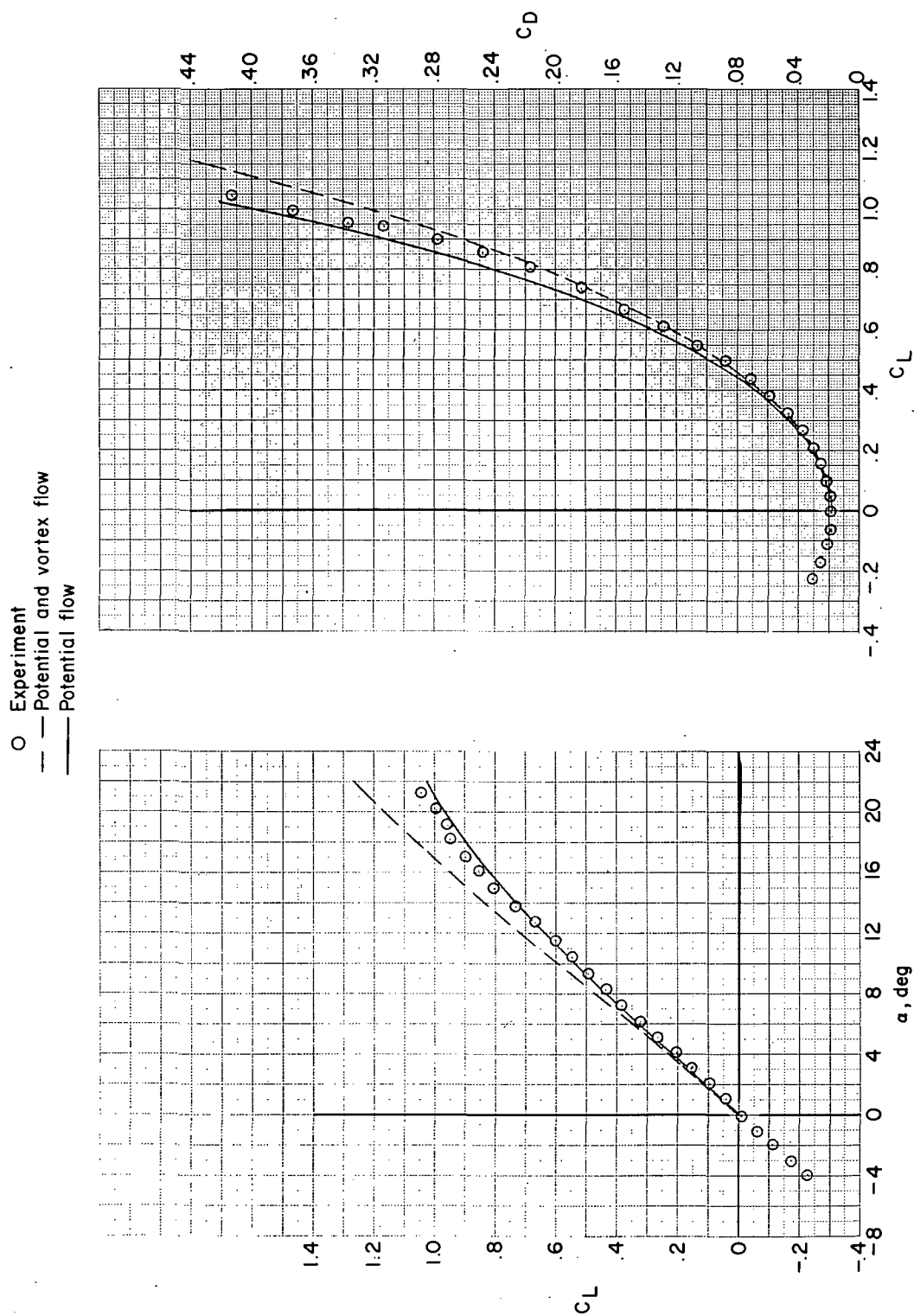


Figure 7.- Comparison of experimental and estimated lift and drag characteristics for the model with the mid wing and low canard locations. Vertical tails off.

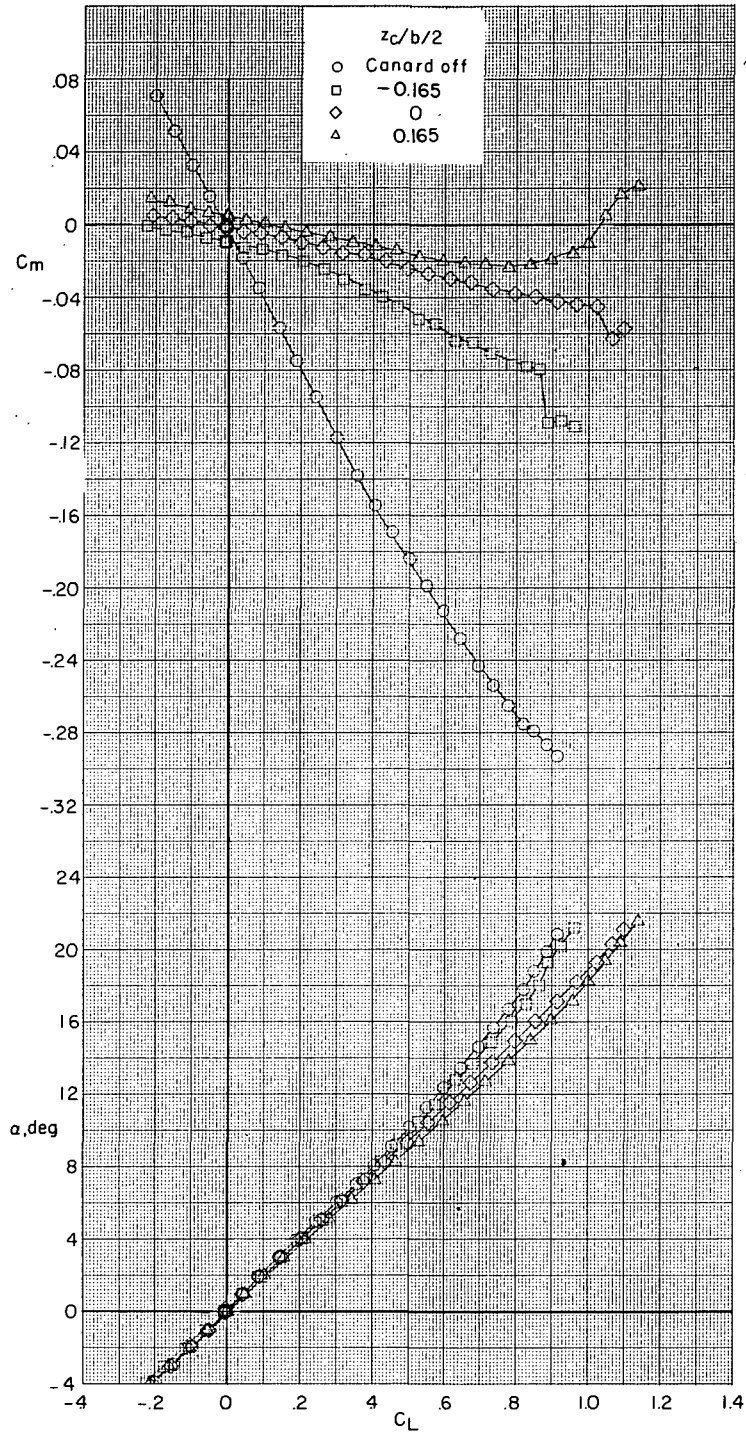


Figure 8.- Effect of canard location on the longitudinal aerodynamic characteristics of the model with mid wing location. Vertical tails located at $0.727b/2$.

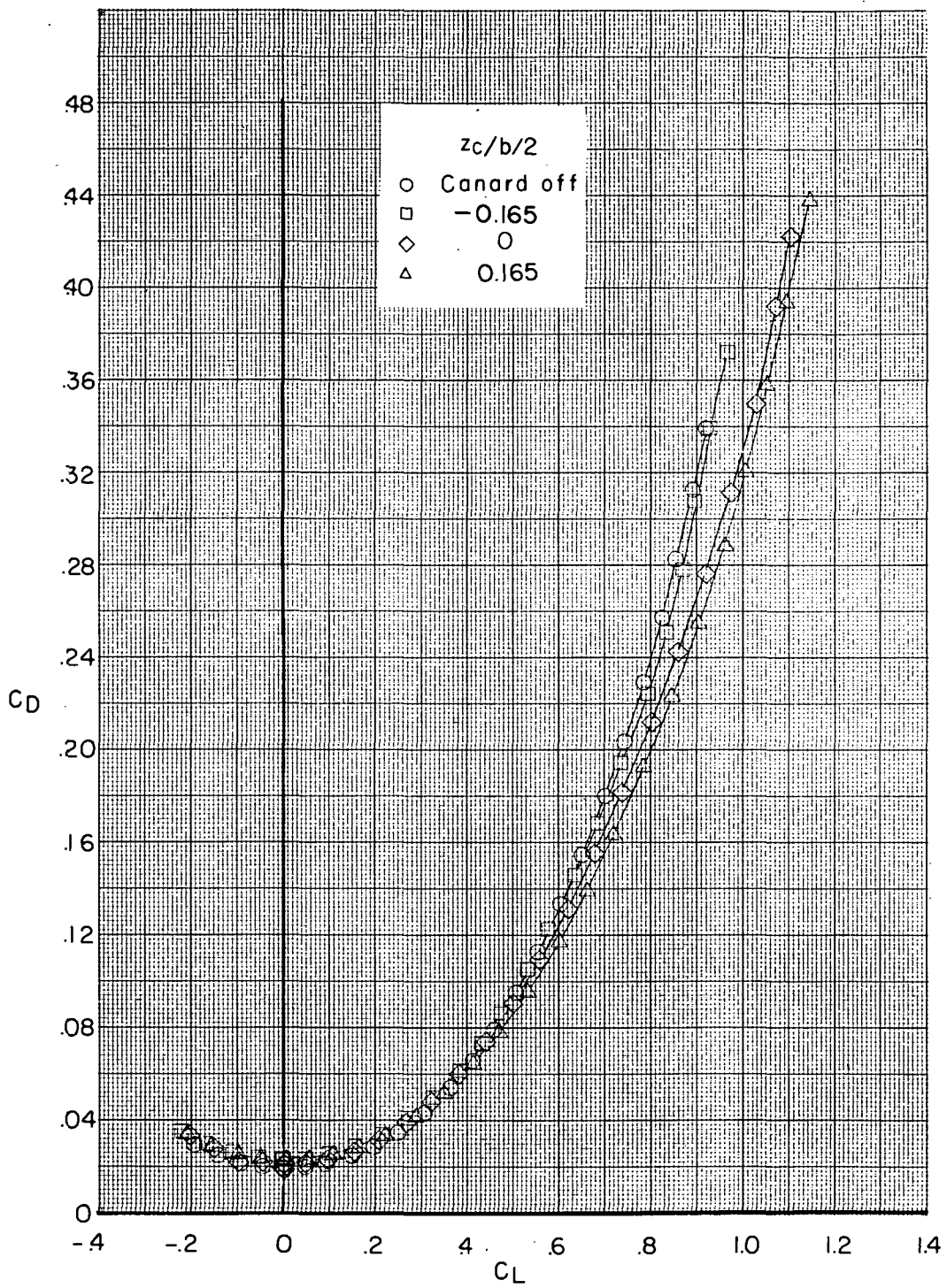


Figure 8.- Concluded.

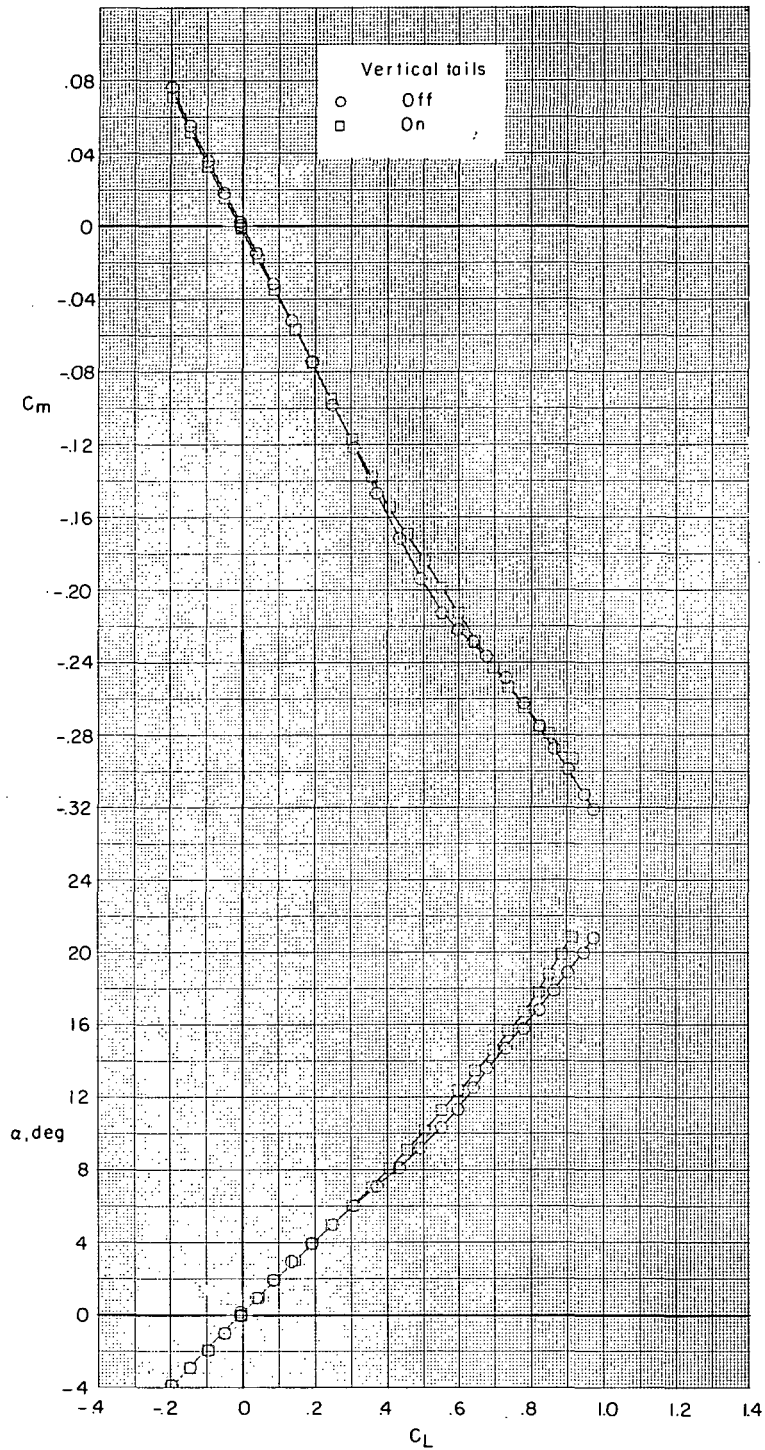


Figure 9.- Effect of vertical tails on the longitudinal aerodynamic characteristics of the model with mid wing location. Canard off and vertical tails located at $0.727b/2$.

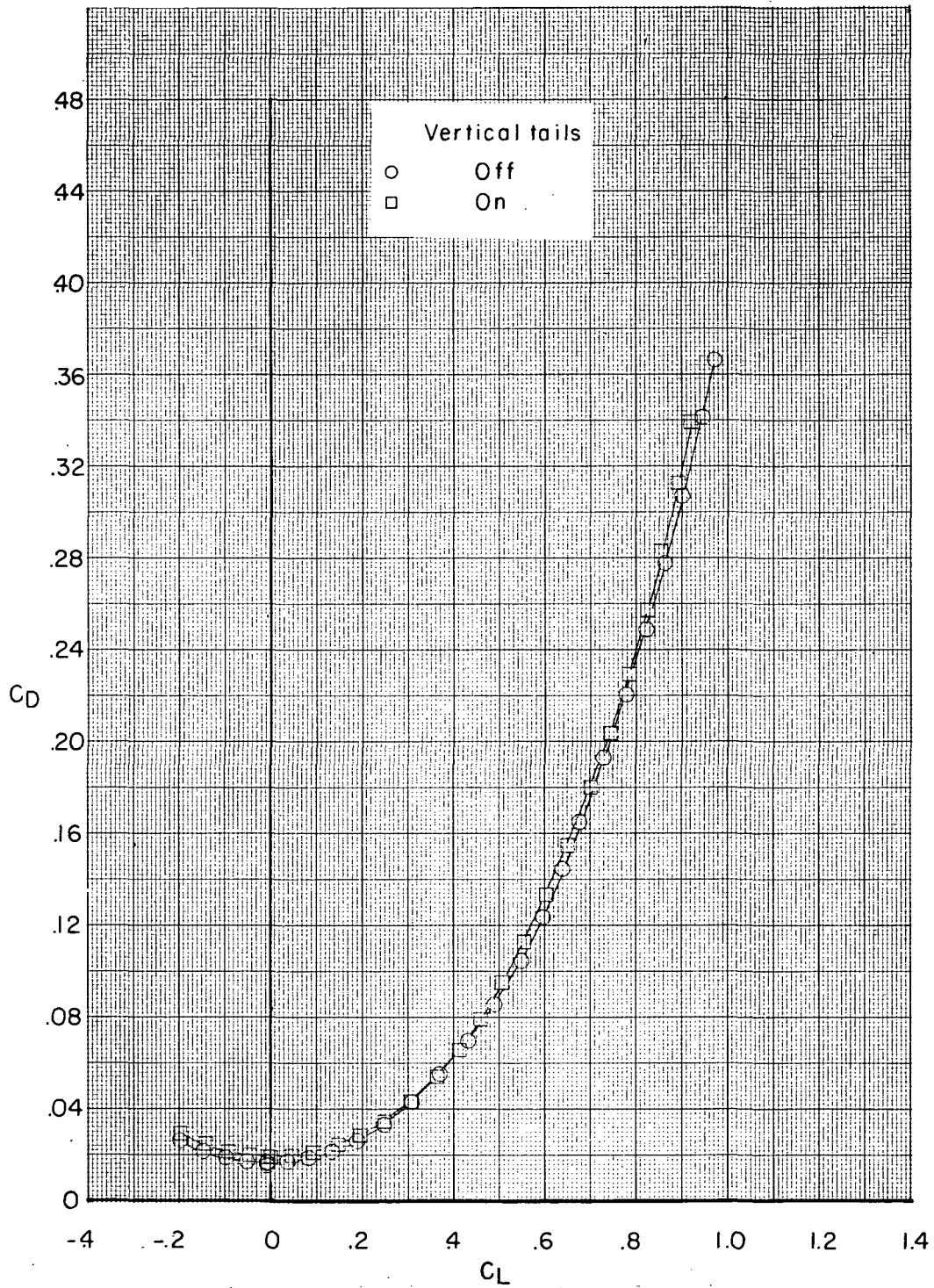


Figure 9.- Concluded.

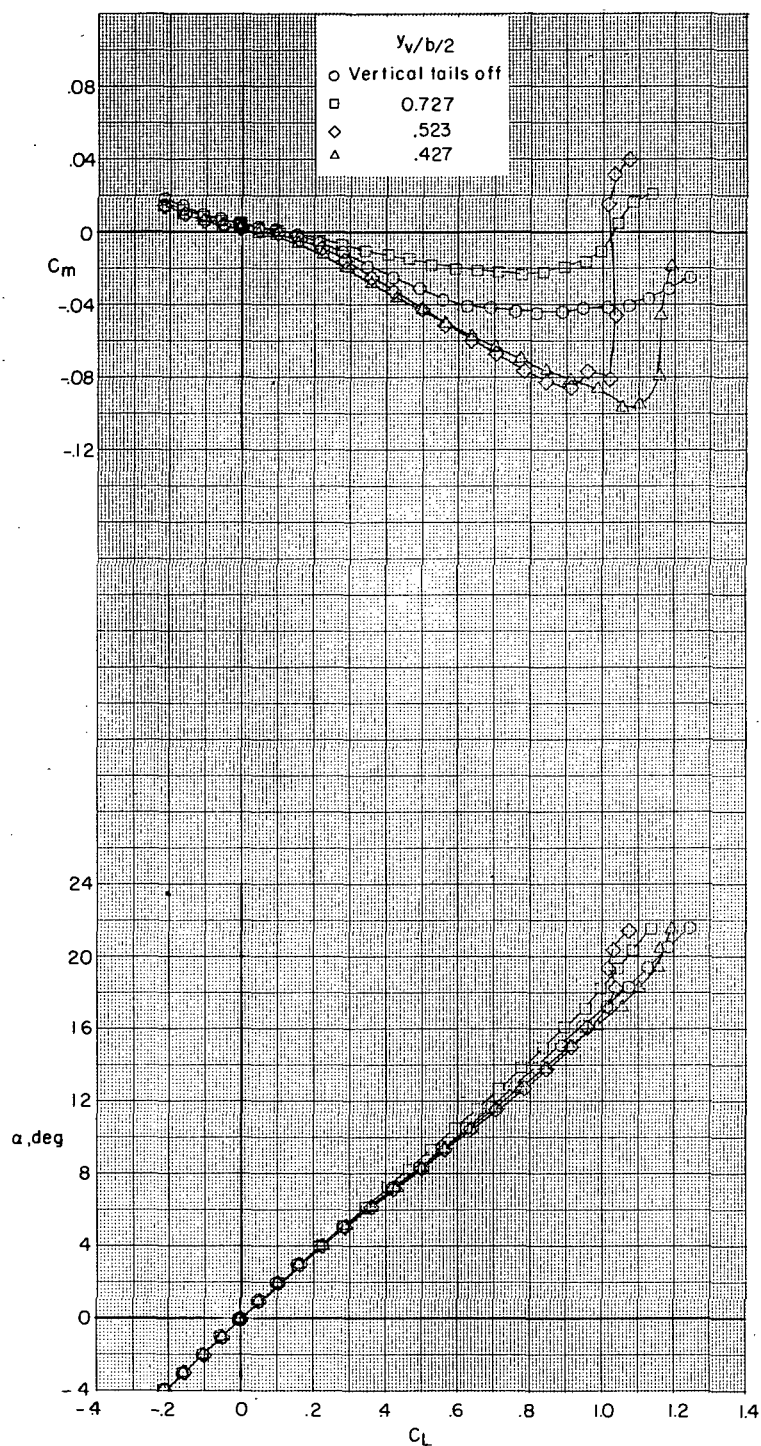


Figure 10.- Effect of vertical-tail spanwise location on the longitudinal aerodynamic characteristics of the model with mid wing location. Canard height location at $0.165b/2$.

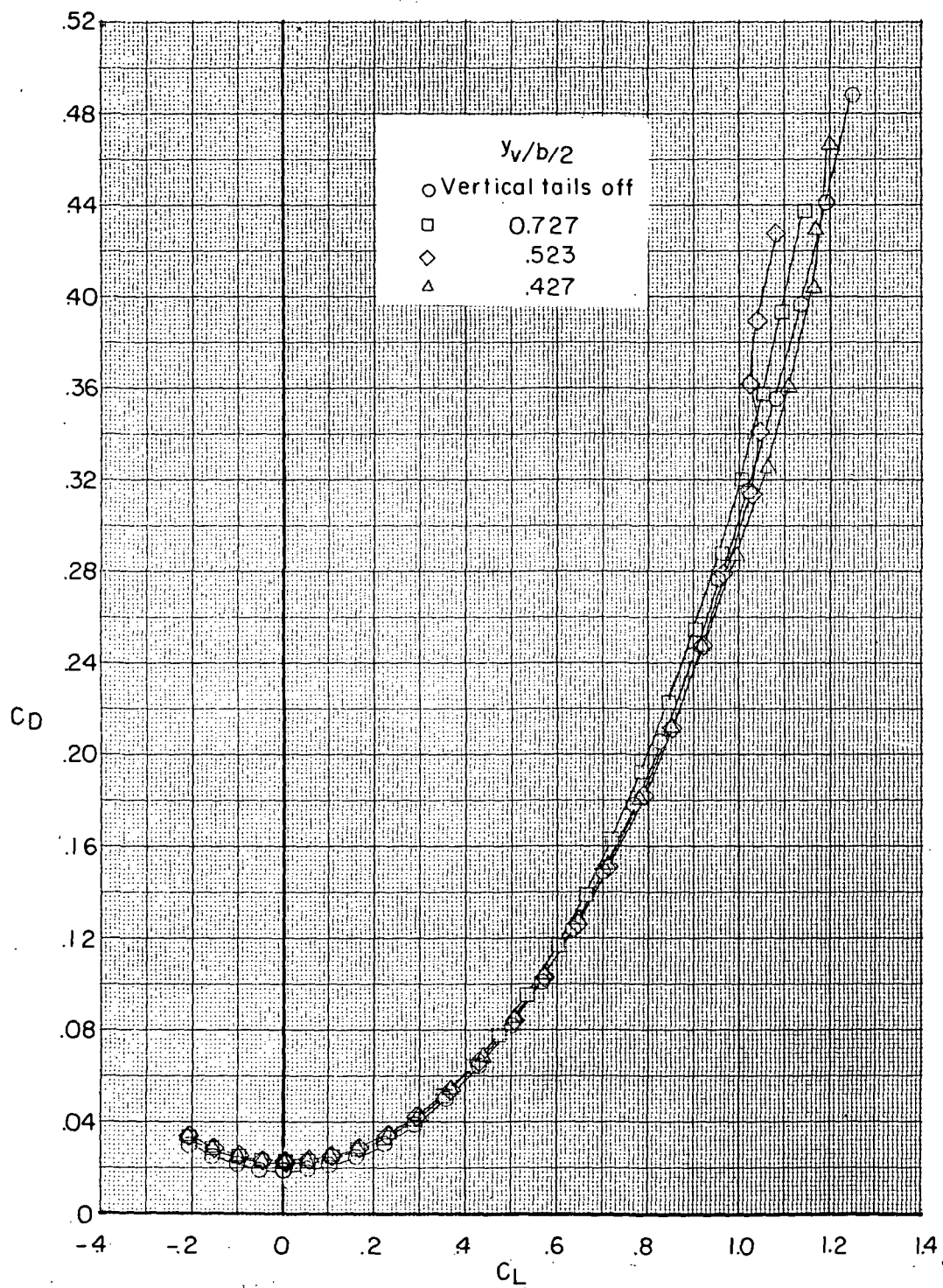


Figure 10.- Concluded.

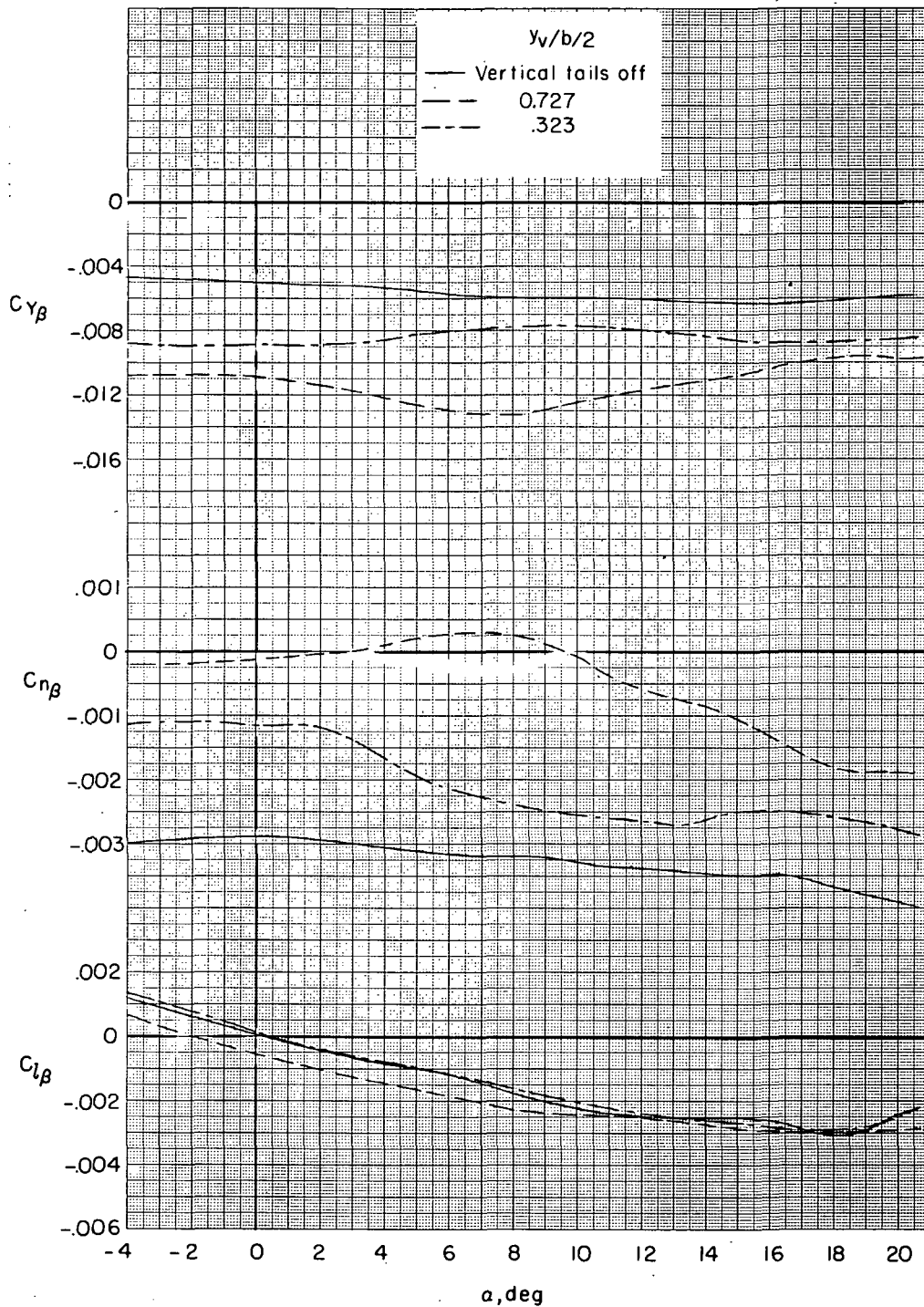


Figure 11.- Effect of vertical-tail spanwise location on the lateral-directional aerodynamic characteristics of the model with mid wing location. Canard height location at $0.165b/2$.

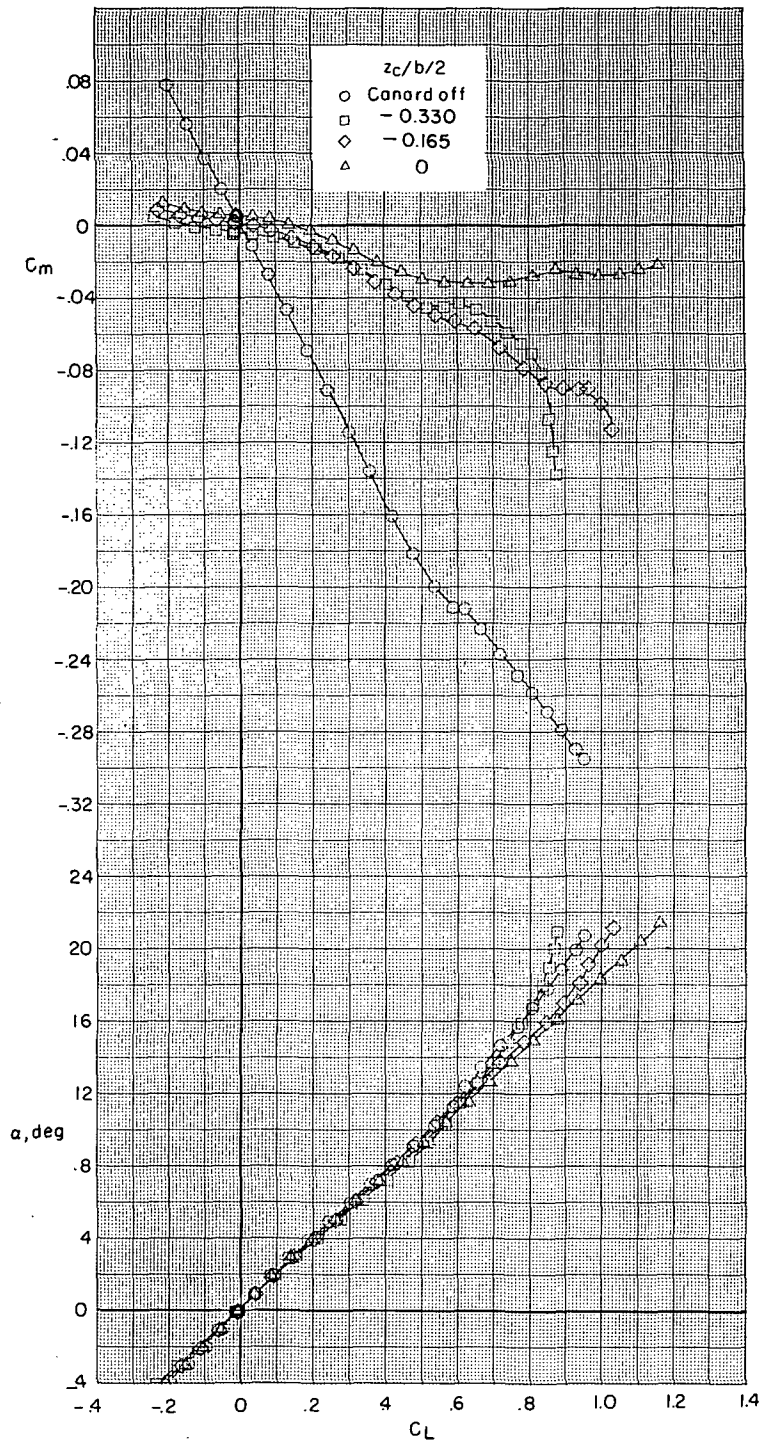


Figure 12.- Effect of canard location on longitudinal aerodynamic characteristics of the model with the high wing location. Vertical tails off.

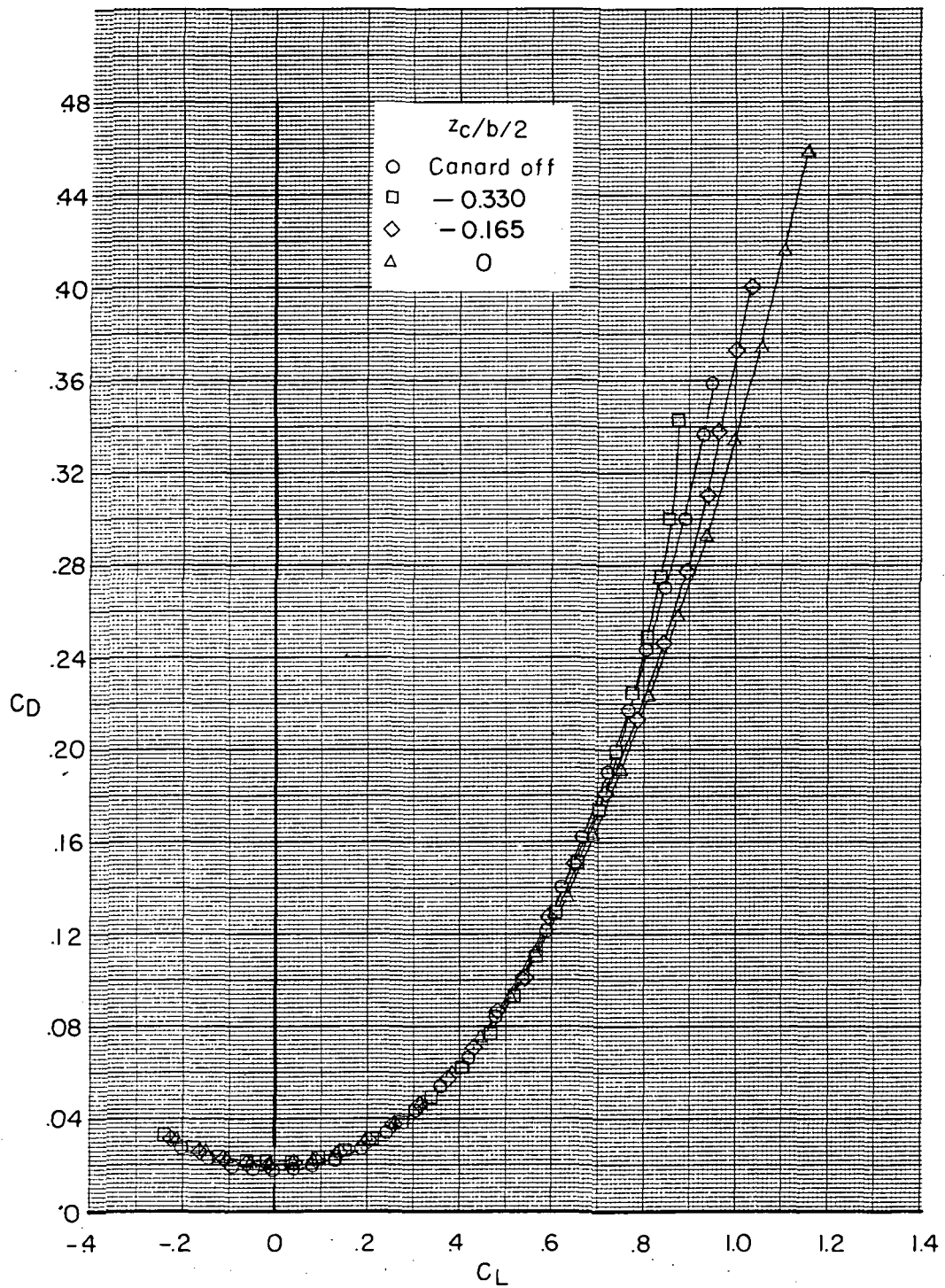


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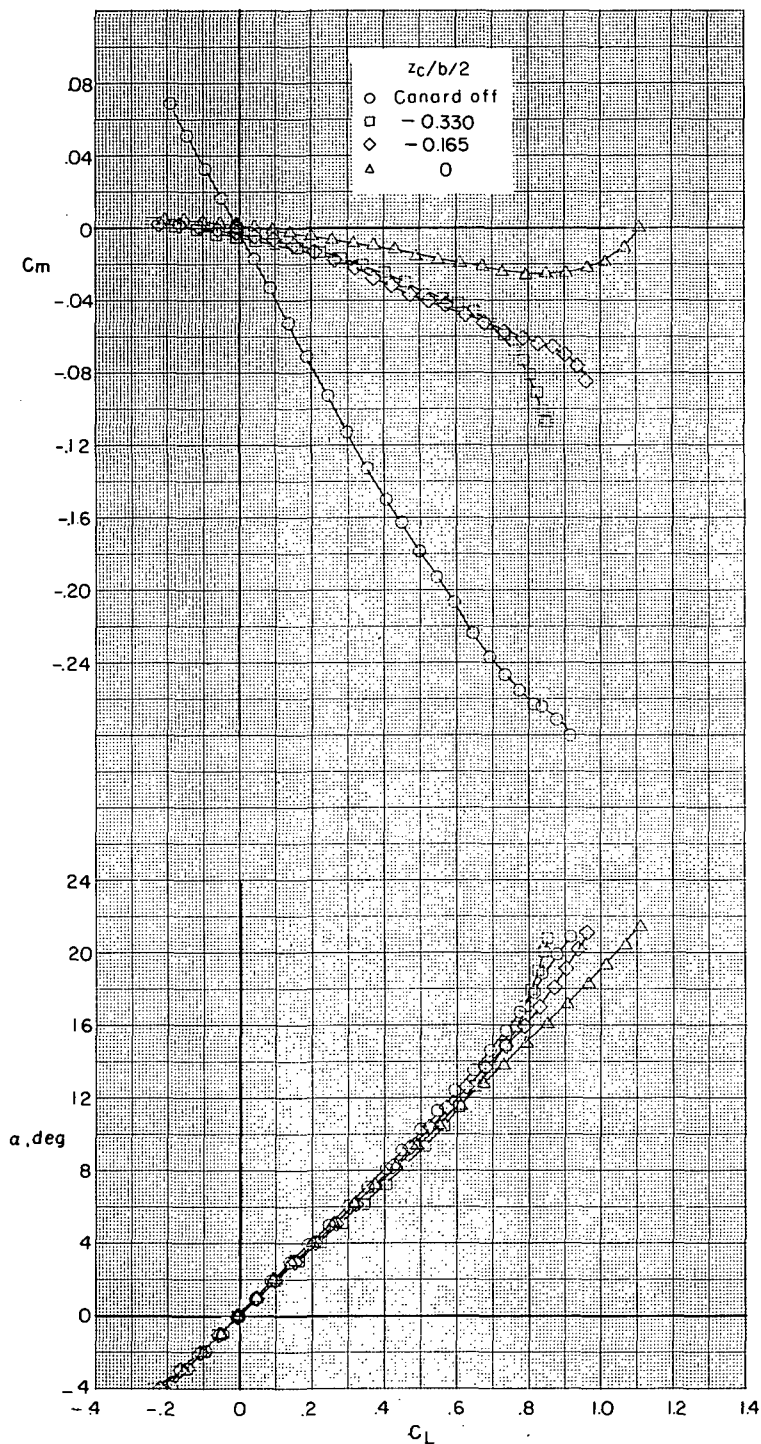


Figure 13.- Effect of canard location on the longitudinal aerodynamic characteristics of the model with high wing location. Vertical tails located at $0.727b/2$.

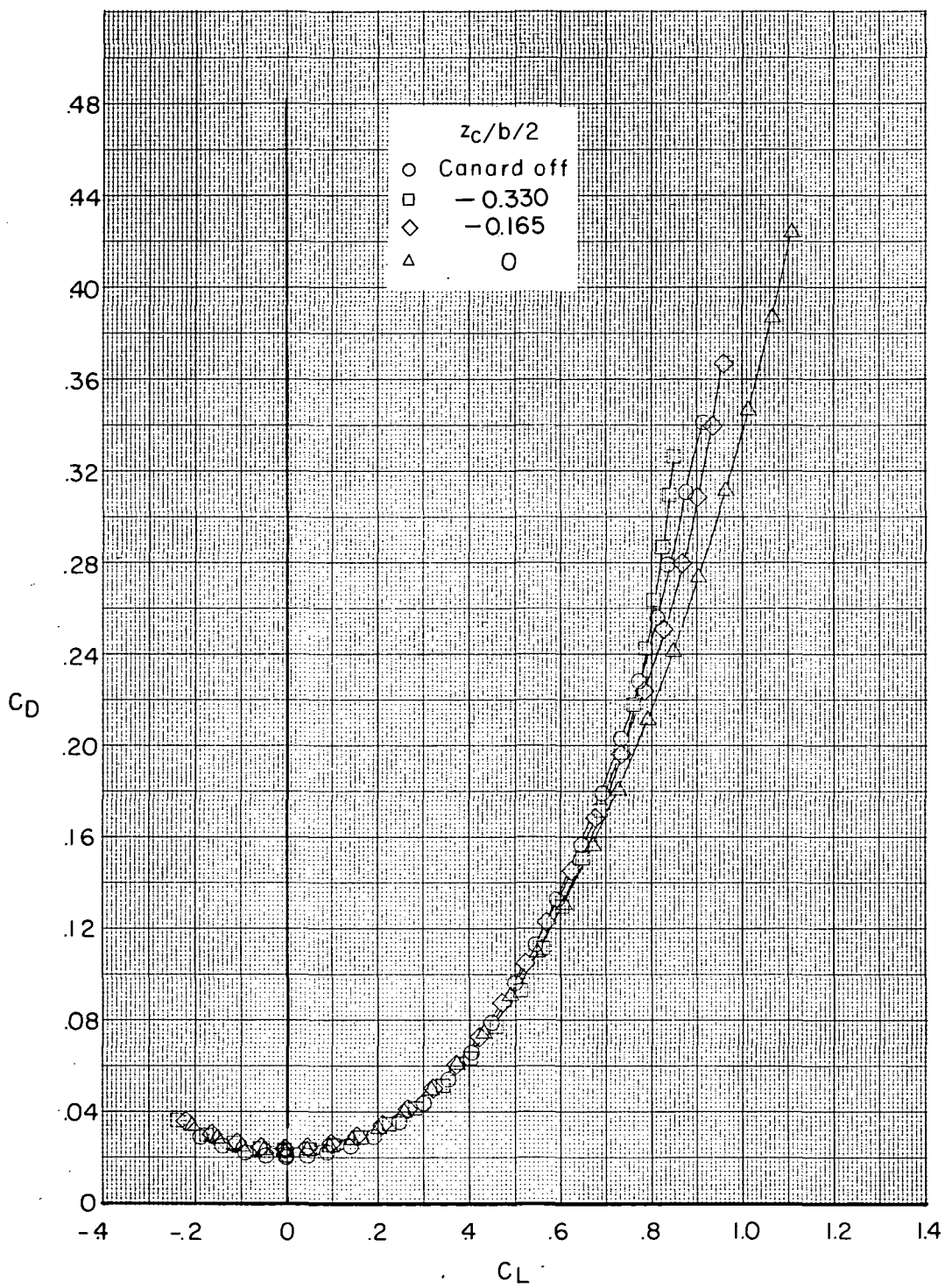


Figure 13.- Concluded.

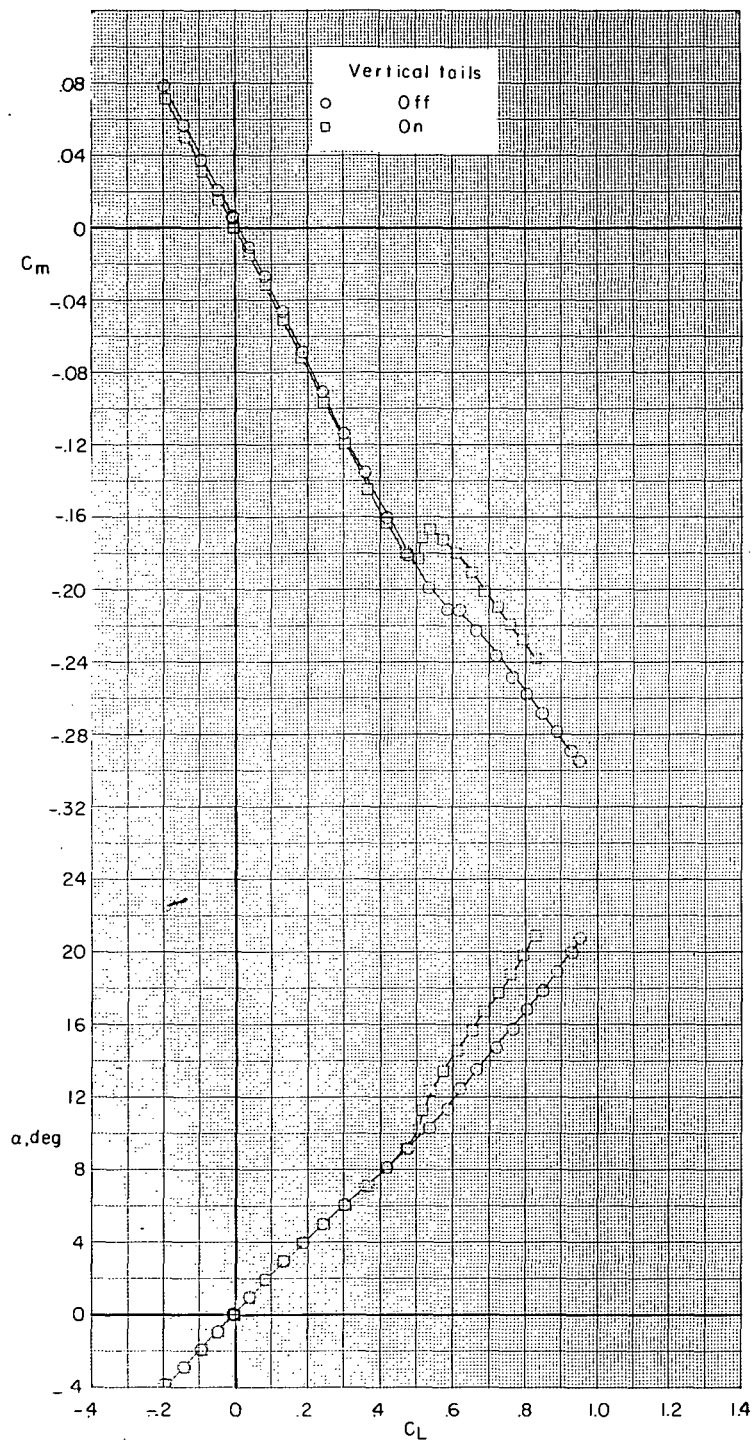


Figure 14.- Effect of vertical tails on the longitudinal aerodynamic characteristics of the model with high wing location. Canard off and vertical tails located at $0.727b/2$.

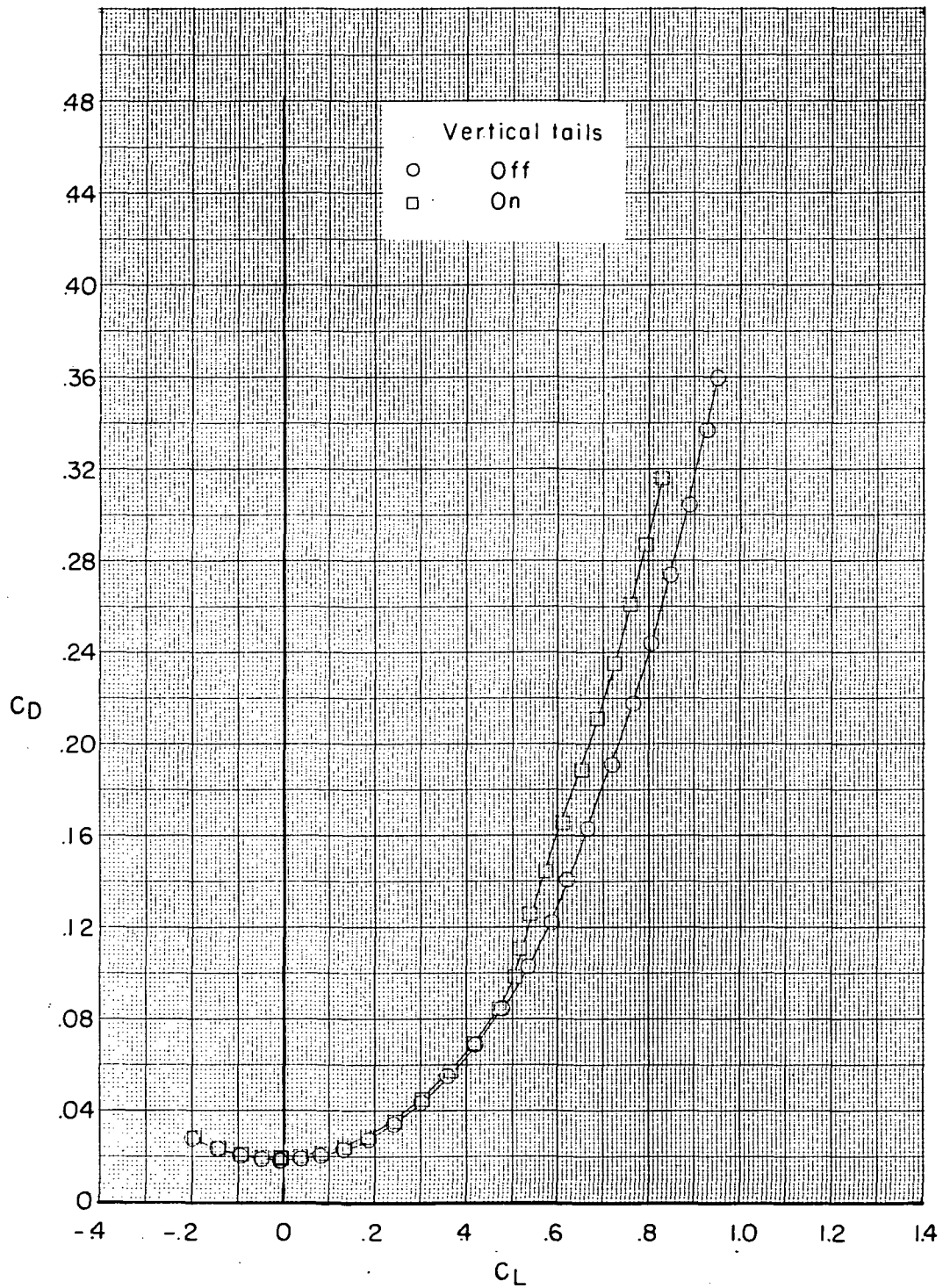


Figure 14.- Concluded.

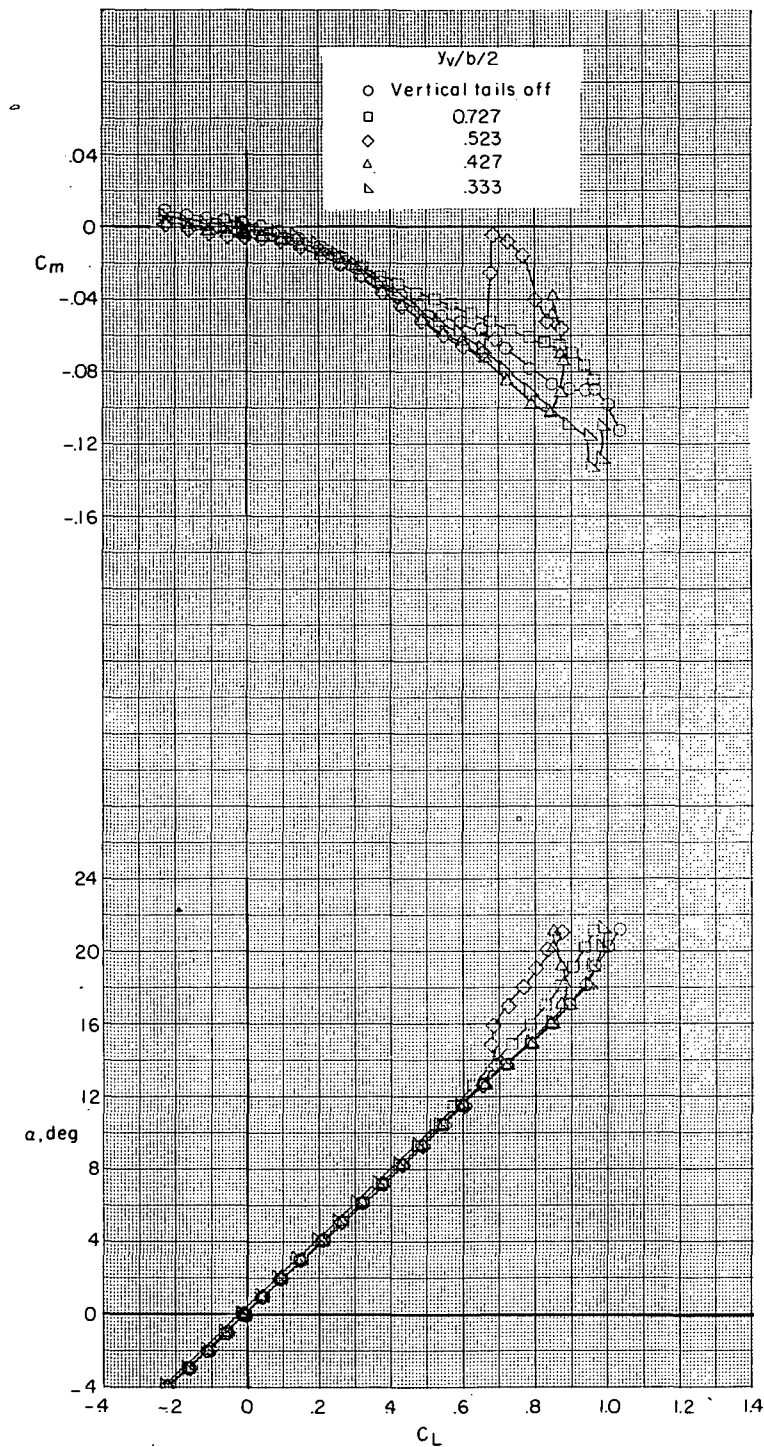


Figure 15.- Effect of vertical-tail spanwise location on the longitudinal aerodynamic characteristics of the model with high wing location. Canard height location at $-0.165b/2$.

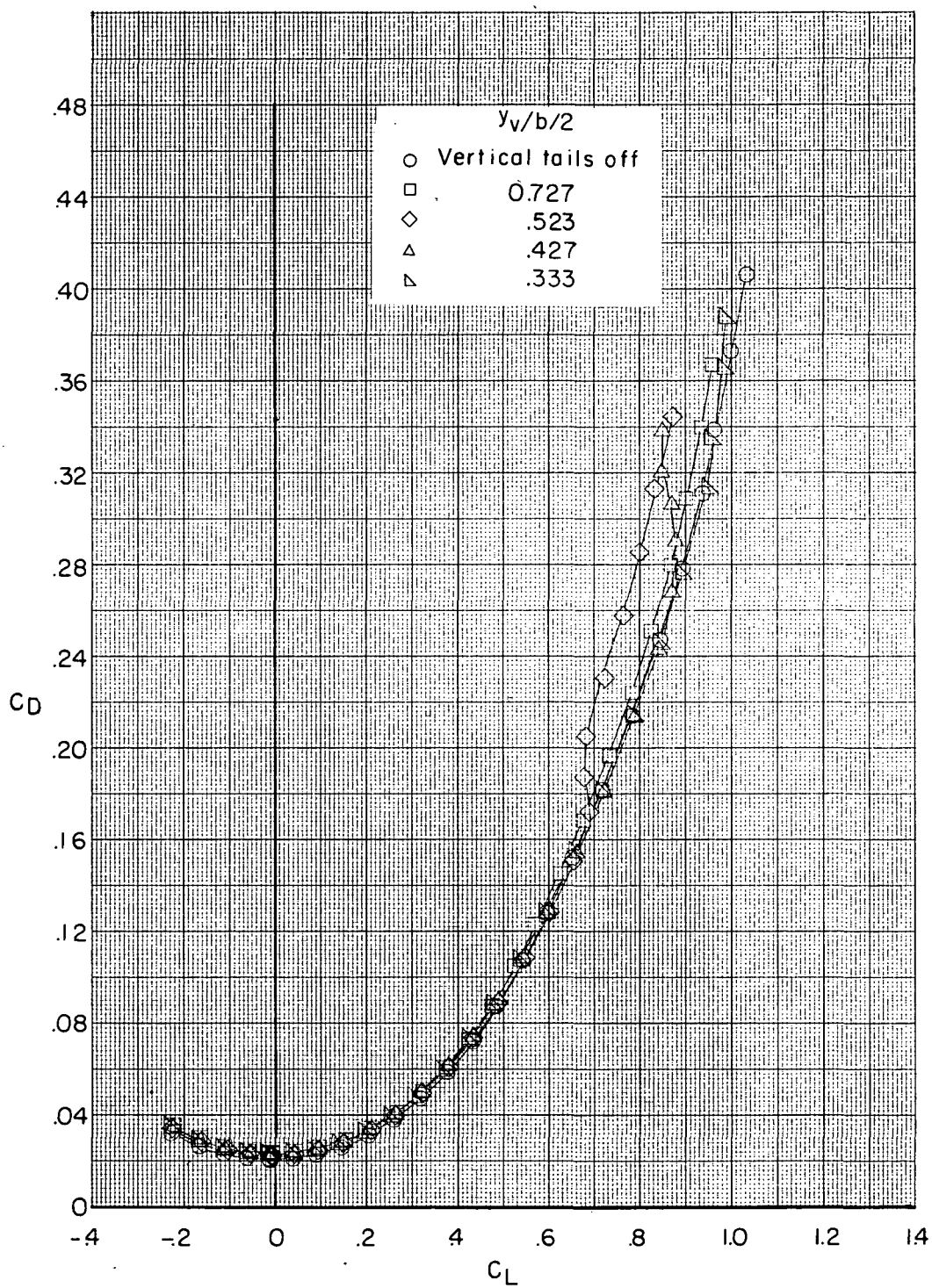


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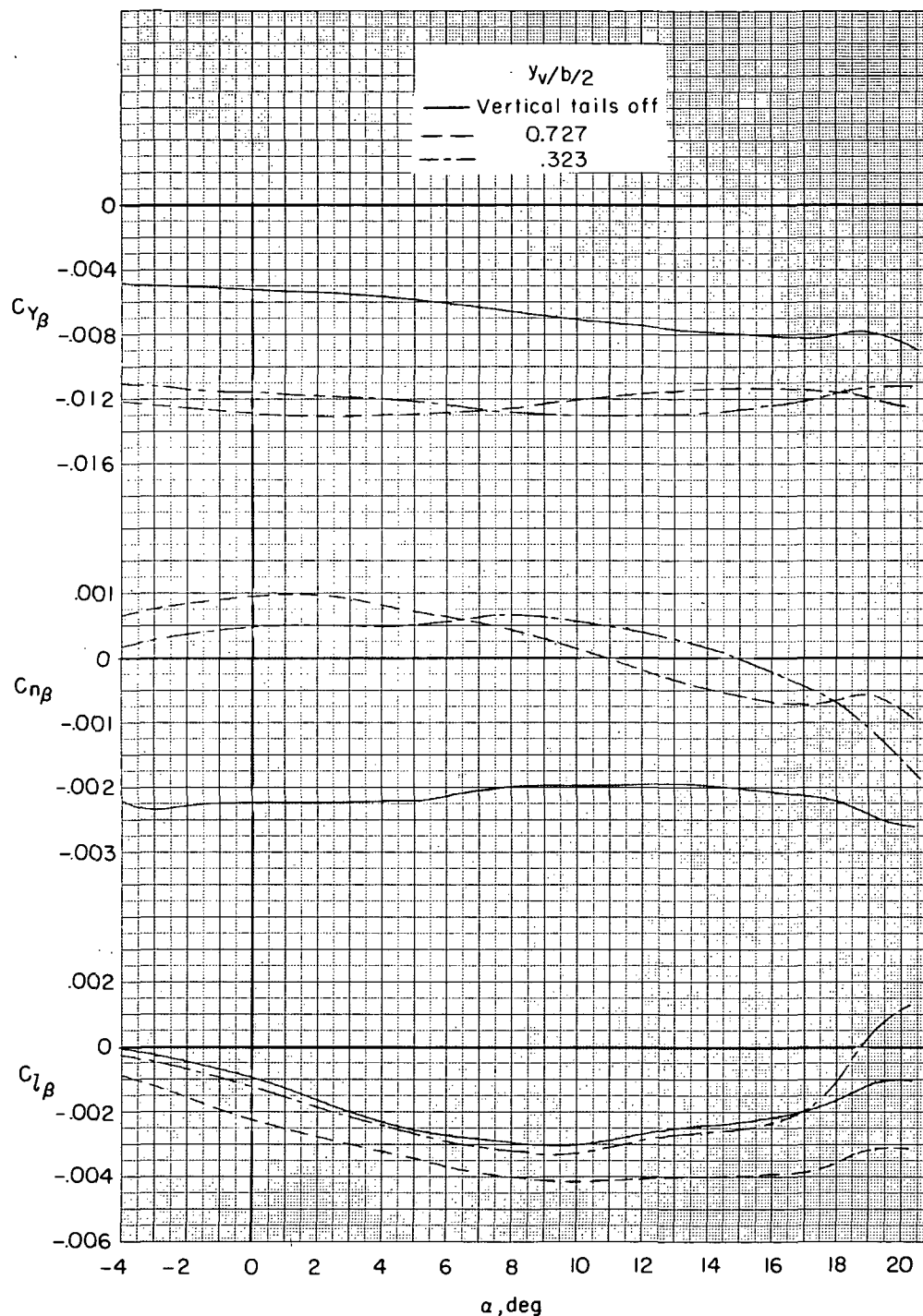


Figure 16.- Effect of vertical-tail location on the lateral-directional characteristics of the model with high wing location. Canard height location at $-0.165b/2$.

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